A Measurement of the Gamma Ray Polarization Sensitivity of Gammasphere

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The Gammasphere array currently in operation at Berkeley has the potential to operate as a γ-ray polarimeter (for linear polarization) by taking advantage of the segmented Ge detectors that will eventually comprise 65% of the completed array.

The polarization sensitivity for this type of segmented detector can be related to the polarization, P, of the radiation through the usual formula $Q(E_\gamma) = A(E_\gamma)/P$, if the experimental asymmetry, $A(E_\gamma)$, is defined (for example) as follows:

$$A(E_\gamma) = \left(\frac{1}{\sqrt{\eta(E_\gamma)}}\right)\left(\frac{\eta(E_\gamma)C(E_\gamma) - S(E_\gamma)}{C(E_\gamma) + S(E_\gamma)}\right) \quad (1)$$

In this relation, $C(E_\gamma)$ and $S(E_\gamma)$ represent the number of confined and shared events in the segmented detectors (i.e. the full absorption events which deposit their energy either confined to one side, or shared between the two sides), and $\eta(E_\gamma)$ is a parameter whose value is determined so as to give zero asymmetry for unpolarized γ-rays.

To determine $Q(E_\gamma)$ we measured asymmetries associated with γ-rays of known polarization [1]. In particular, we looked at γ-rays from excited states in ^{24}Mg, ^{56}Fe, and ^{109}Ag which were populated following inelastic scattering of protons at E_p=2.46, 3.0 and 2.54 MeV respectively. This allowed determination of $Q(E_\gamma)$ at 1.368 MeV, 0.847 MeV, and 0.415 MeV respectively. The $\eta(E_\gamma)$ parameter for these experiments was determined as a function of E_γ by using a ^{152}Eu source placed at the target location. Figure 1 shows (by the solid data points)the results for $Q(E_\gamma)$. A computer Monte Carlo simulation was also performed to compare with these experimental values. In this simulation, the γ-ray polarization vector was rigorously tracked so as to give realistic azimuthal Compton scattering for all the multiple interactions of each γ-ray. The results of these calculations (along with the associated errors) are shown by the open data points in Figure 1. A solid line connects these points. The agreement between experiment and theory is seen to be good. The dashed line in Figure 1 is the energy dependence of the Klein-Nishina formula in a point detector approximation [1]. This energy dependence is the one which is traditionally used to fit $Q(E_\gamma)$ data from 4-fold segmented polarimeters. However, due to the 2-fold segmented nature of the current geometry, this energy dependence is seen to be inadequate. In particular, the side-photoabsorption at low energies is seen to reduce Q.

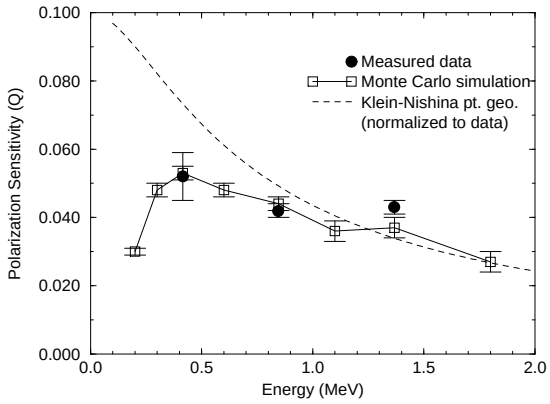

Figure 1: The experimental results for Q are compared to theoretical energy dependences.

References

[1] P.M. Jones *et al.*, NIM **A362**,556 (1995)